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A sealed flint knapping site from the Younger Dryas in the Scheldt valley (Belgium): Bridging the gap in human occupation at the Pleistocene–Holocene transition in W Europe

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ABSTRACT

Based on the evidence of a recently excavated, sealed site, situated at Ruien "Rosalinde" in the Belgian Scheldt valley, the response of hunter-gatherers to changing climate at the transition from the temperate Allerød to the cold Younger Dryas is discussed. Radiocarbon dated to the end of the Allerød or the very beginning of the Younger Dryas, the site of Ruien provides the earliest evidence of a refined lithic technology characterized by the use of a soft stone hammer and the production of straight and regular blade(let)s from intensively prepared cores with two opposite platforms and sharp striking angles. In the course of the Younger Dryas and Early Pre-boreal this knapping method will become standard all over Europe, from the Tanged Point Technocomplex in the North to the (Epi)Laborian in the South. It contrasts sharply with the knapping style of previous lithic traditions, such as the late Federmesser/Azilian and Bromme Technocomplexes, which was much less elaborated and mainly oriented towards the knapping of short irregular blades with a hard stone hammer. This apparently abrupt technological change was also accompanied by increased raw material procurement networks, extending over up to 250 km, and a marked microlithisation of the hunting equipment. Finally, the site of Ruien is also important as it demonstrates the limited archaeological visibility of Younger Dryas sites, explaining the scarcity of such sites within western Europe.

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1. Introduction

Despite long-term and extensive interdisciplinary research into the Late Glacial (Final Palaeolithic) and Early Holocene (Mesolithic), the Scheldt basin in western Belgium still completely lacks evidence of human occupation dating to the Younger Dryas (YD) and Pre-boreal (PB) (Crombé and Verbruggen, 2002; Crombé et al., 2014). This contrasts sharply with the very high site density during the preceding Allerød and posterior Boreal, when the Scheldt basin was occupied by hunter-gatherers belonging respectively to the *Federmesser* Culture (or Curve-Backed Point Groups, CBP) and the Early Mesolithic (Crombé et al., 2011, 2013b). Except for some stray-finds of lithic armatures (Crombé et al., 2013b; Devriendt et al., 2010), no clear occupation sites belonging to either the (Epi)Ahrensburgian or (Epi)Laborian are currently known, resulting in an apparent occupation hiatus of ca. 2 millennia. A similar occupational gap has been attested in other research areas within western Europe (Fig. 1), e.g. in northern and western France (Fagnart and Coudret, 2000; Naudinot, 2013; Valentin, 2008), western Netherlands (Arts and Deeben, 1981) and Britain (Barton and Dumont, 2000). Except for a series of special purpose sites belonging to the Bruised/Long Blade or Belloisian Technocomplex (Barton, 1998; Barton and Dumont, 2000; Fagnart, 2009; Valentin, 2009) and dated to the transition from the YD to the PB, less than ten sites (Ercheu, Vieux-Moulin, Reuil-Malmaison, La Fosse, etc.)

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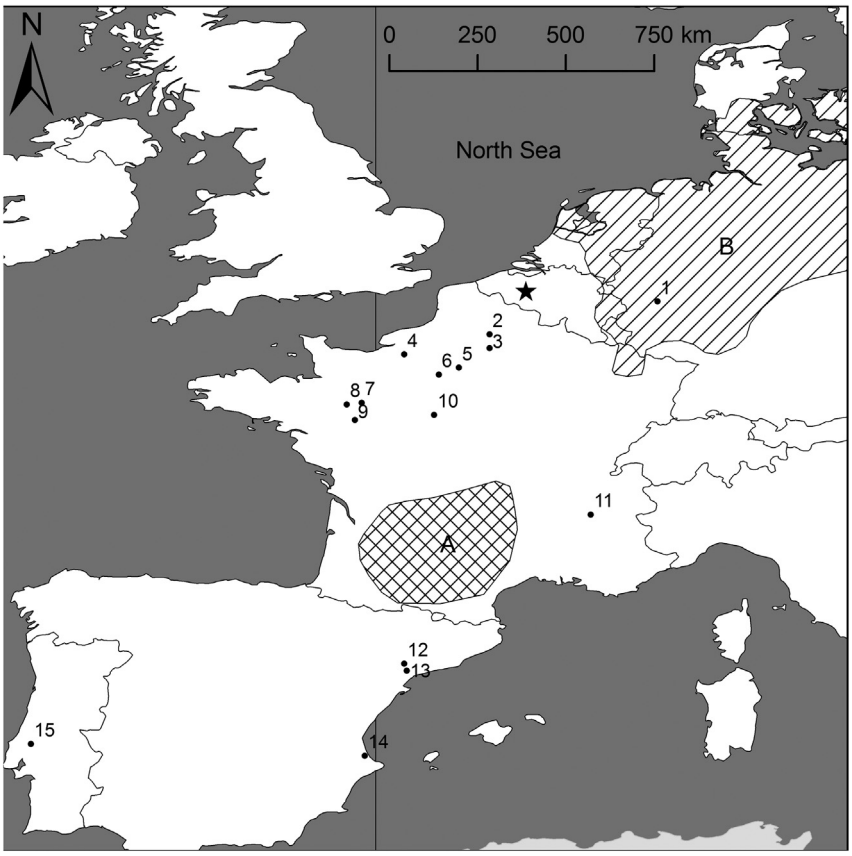


Fig. 1. Distribution map of lithic traditions dated to the Younger Dryas/early Pre-boreal (Bruised Blade sites not included). Key: A. Core area of (Epi)Laborian Technocomplex; B. Core area of Tanged Point Technocomplex; Black dots: Intermediate sites presenting affinities with the TPC and/or (Epi)Laborian. Black star: the site of Ruien (based on Arts and Deeben, 1981; Langlais et al., 2014). Sites: 1. Bad Breisig 2. Ercheu 3. Vieux-Moulin 4. Calleville 5. Le Closeau 6. Blanchères 7. La Fosse 8. Camp d'Avours 9. La Guichaumerie 10. Muides 11. Colomb/La Passagère 12. Hort de la Boquera 13. Sant Gregori 14. Mallaetes 15. Carneira.

within this vast territory along the Atlantic coast may be attributed to the cold YD (Fig. 1). However, the chronology of most of these sites is not supported by secure radiocarbon dates, but based on techno-typological characteristics of the lithic assemblages.

In contrast the North European Plain has yielded very substantial evidence of continued albeit adapted human occupation during the cold YD. Sites belonging to the Tanged Point Technocomplex (TPT) (Burdukiewicz, 2011; Terberger, 2004; Weber et al.,, 2011), including the Ahrensburgian and Swiderian Cultures, occur in dense clusters throughout the eastern Netherlands, northern Germany, northern Poland and southern Scandinavia (Fig. 1). This marked difference in site density between northern and western Europe still remains unexplained. However, most scholars assume it reflects a major difference in population density induced by differential environmental response to the decreasing climate of the YD (Barton and Dumont, 2000; Fagnart and Coudret, 2000; De Bie and Vermeersch, 1998). According to a recent analysis by Weber et al. (2011) the opening of the landscape and the re-establishment of presumably reliable reindeer migration patterns might be the reason why human occupation and behavior stabilized in the northern lowlands. On the other hand in western Europe the climatic deterioration of the YD led to unstable environmental conditions, such as increased erosion especially along the deforested hill flanks leading to the deposition of thick sediments in the river valleys (Antoine et al., 2000; Fagnart, 1997: 232; Valentin, 2008: 173–174), possibly making the area less suitable for continued occupation after the Allerød. Still, it should be questioned whether the scarcity of YD sites in this area is not biased by taphonomic factors. How sure are we that we are not missing most sites in western Europe, e.g. due to erosion and/or sedimentation of thick colluvial or fluvial deposits? Also it needs to be investigated whether western lithic traditions are not archaeologically less visible due to a lack or scarcity of diagnostic artifacts, such as the typical tanged points from the northern TPT or the Malaurie and Blanchères points from the southern (Epi)Laborian. Within the (Epi)Ahrensburgian, for example, lithic assemblages lacking tanged points are dominated by microlithic armatures closely related to the later, Mesolithic ones (Veil, 1987; Crombé et al., 2014; Deeben et al., 2000). Similarly within the Epilaborian microliths are often well represented (Naudinot, 2013).

The fortuitous discovery of a well preserved camp-site dated to the beginning of the YD at Ruien in the Belgian Scheldt valley opens new perspectives in this debate. Situated in the transitional area between the northern and western YD technocomplexes (Fig. 1) it has the potential to address the above questions about human occupation at the transition from the Pleistocene to the Holocene.

2. The archaeological site of Ruien "Rosalinde"

The prehistoric site of Ruien "Rosalinde" is situated on the right bank of the Scheldt River in NW Belgium (coordinates 50°46′23″N/3°28′51″E) (Fig. 2). Located on a low-lying, ca. 16 m TAW (= mean low water tide level in Oostende) SW–NE oriented loamy ridge, it is bordered to the north by the Lateglacial floodplain of the Scheldt and to the south by the relatively steep flank of the Kluisberg. The latter constitutes one of the highest elevations within the Scheldt

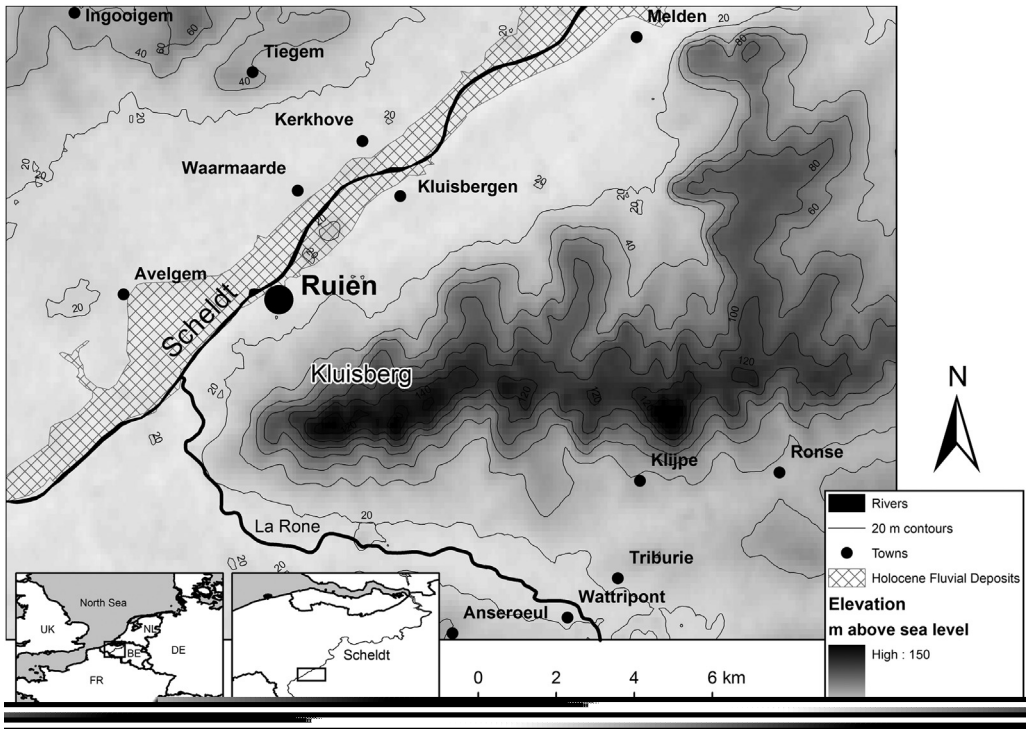


Fig. 2. General location map of the prehistoric site of Ruien "Rosalinde".

valley (ca. 140 m TAW) and is composed of tertiary sediments, consisting of alternating layers of sand and clay. In the top layer, belonging to the Diest Formation (Jacobs et al., 1999), local banks with ferruginous sandstones occur protecting the Kluisberg from erosion. The prehistoric site is situated in between two thalwegs along the northern hill flank, the remains of which have been found during excavations.

The site was fortuitously discovered in 2011 by the regional archaeological service SOLVA during the salvage excavation of an Iron Age and Roman settlement site. The first prehistoric finds were collected from (pre)historic settlement features, but it was also noted that some artifacts were present outside features in the surrounding sediment. This prompted the excavators to further investigate the undisturbed soil resulting in the detection of a well preserved prehistoric level with clusters of lithic artifacts and associated features.

3. Material and methods

3.1. The excavation

Since the prehistoric site is situated along the northwestern limit of the excavation it can be assumed that only part of the site was investigated (Fig. 3). In total a surface of ca. 5000 m^2 was investigated by means of a combination of test-pits and augerings. In the zone (ca. 220 m^2) which yielded the first lithic artifacts, test-pits of ¼ m^2 were excavated with an interval of 1.5 m in a staggered grid. Around each positive test-pit additional ¼ m^2 squares were excavated to a point where no artifacts were found any more. In the end a zone of ca. 40 m^2 was continuously excavated in artificial layers of 10 cm. Almost all artifacts >1 cm were registered three-dimensionally and the excavated soil wet-sieved through meshes of 2 mm. Beyond this excavated zone, the sector was further assessed by means of manual drillings set in a staggered grid of 5 m. In total 178 bore-holes with a diameter of 15 cm were investigated by wet sieving through meshes of first 0.5 mm and later 2 mm width.

3.2. Pedological analyses

A ca. 5 m long, SW–NE oriented soil profile in the center of the prehistoric site at the level of two anthropogenic features (Fig. 4) was described and divided into 4 genetic soil horizons (H1–H4).

3.3. Archaeological analyses

The lithic assemblage has been studied by means of a detailed morpho-typological and morpho-technological attribute analysis. The technological approach was mainly based on the work of Pelegrin (1995) on "mental refitting". The study focused on attributes which are indicative for the methods and techniques used to produce lithic artifacts and which are macroscopically observable and measurable. The selected attributes are related to raw material (texture, cortex, color, weathering, …), the removals larger than 1 cm (termination, cross-section, curvature, butt type, presence/absence of bulb, lip, splinters, ridges, fractures, core edge rejuvenation, number, orientation and pattern of dorsal negatives) and cores (general morphology, position and preparation of core faces and striking platforms, negatives, knapping edge and core edge rejuvenation). Artifacts smaller than 1 cm (e.g. chips) were only recorded for raw material and weathering (traces of burning, frost, …). Physical refitting is planned for the near future.

3.4. Radiocarbon dating

A black ash-layer underneath a stone-built hearth was used to obtain two radiocarbon dates for the prehistoric occupation. Both samples were pre-treated in different ways. Sample 1 was prepared with AAA (HCl–NaOH–HCl, all 1%), each step for 1 h at 90 °C to remove exogenous carbonates and humic acids, rinsed several

Both pre-treated samples were transferred into quartz tubes with CuO and Ag and combusted to CO_2 at 400 °C. A combustion temperature of 400 °C was chosen to minimize the contribution of the more refractory carbon bound to clay minerals in the sample (McGeehin et al., 2001, 2004). Graphitization of CO_2 was carried out using H_2 over a Fe catalyst. Targets were prepared (Van Strydonck and Van der Borg, 1990–1991) and ^{14}C concentrations were measured with Accelerated Mass Spectrometry (AMS) at the Royal Institute for Cultural Heritage in Brussels (Belgium) (Boudin et al. in prep). Radiocarbon results are expressed in pMC (percentage modern carbon) and indicate the percent of modern (1950) carbon corrected for fractionation using the $\delta^{13}C$ measurement. Calibrations of ^{14}C dates and χ^2-test (weighted mean) calculations were performed using OxCal 3 and the IntCal13 calibration curve data (Shennan, 1988; Bronk Ramsey, 1995, 2001; Reimer et al., 2013).

3.5. Analysis of red-colored feature

In the field a shallow red-colored feature was tentatively interpreted as an ochre patch, based on visual similarities with features found on other prehistoric sites (Deeben and Schreurs, 2012). In order to verify this, four soil samples were taken from the feature (P2, JS1) as well as immediately aside (P1 and P3) for chemical and mineralogical analyses (Fig. 4). In addition a sample was taken from the feature for micromorphological analysis.

The chemical composition of all samples was determined with p-XRF. First the boxes were dried at 30 °C, as a varying water content will influence the results of the light elements (Mg, Al, Si, P, S and Cl). After that the analyses were performed with a Thermo Scientific Niton XL3t p- XRF with GOLDD + detector equipped with a silver anode operating at a maximum of 50 kV and 40 μA. The device is well suited for the measurement of up to 25 simultaneous elements in the analytical range between sulfur (atomic number 16) and uranium (atomic number 92) as well as light elements (Mg, Al, Si, P and Cl). All analyses were performed in bulk mode ("mining mode"). The device is factory calibrated and further soil reference materials are measured for external standardization. Measuring times were 110 s using 4 different energy settings for light (Al, Si, P, S, Cl; 40 s), low (Ca, K, Sc, Ti; 20 s), main (K-lines from V until Ag and L-lines from Au until Pb; 40 s) and high (Ag until Au; 10 s).

In addition XRD analysis was performed on the small sample (JS1), using a Bruker XRD D8 with GADDS detector. Detection limits for minerals are about 1%.

The micromorphological sample was taken with a Kubiena type box and sent to Julie Boreham at EarthSlides in Cambridge UK for thin section preparation, i.e. impregnation with resin, sawing, lapping and polishing to a thickness of ca. 30 micron. All sections were studied in the micromorphological laboratory of the Cultural Heritage Agency in Amersfoort, using a Wild M420 Macroscope and Zeiss Axioskop 40 polarizing microscope, both fitted with Zeiss MRc5 digital cameras. Scans of the thin sections were made using a Epson V750 pro slide-scanner.

3.6. Analysis of the hearth stones

In order to determine the origin of the sandstones used to construct a hearth as well as the genesis of the reddish coloring observed on the outer side of some hearth stones, 4 samples, including 1 ferruginous sandstone (sample 514) and 3 glauconiferous sandstones (609, 514 & 20–30) were selected for further analysis. 30 μm thin sections were prepared for petrographic identification using a Zeiss Axioscope, covering a sagittal section from the discolored crust to the unaffected rock core. Rock powders were drilled from both the discolored sample crust and the sample's interior for further analysis with X-Ray Diffraction, Differential Scanning Calorimetry and selective iron extraction using dithionite-citrate extraction (DCB) (De Kock et al., submitted for publication).

4. Results

4.1. Lithostratigraphy

The studied reference profile (Fig. 4) (Table 1) shows a normal sequence of morphogenetic horizons, which together illustrate the Holocene soil evolution and degradation. Most probably the soil originally contained a fraction of calcium carbonate, which today has been completely leached out of the observed soil. Once the soil was decalcified, it became liable to small scale clay migration from H3 to H4, which was confirmed by the presence of shiny clay coatings in the micromorphological study of the thin-sections (cf 4.4). Concomitantly iron migration occurred partly together with the clay, partly due to seasonal water level fluctuations with changes in oxygen level causing iron to become mobile (cf 4.4).

H1 is the present day plow layer that can be followed throughout the excavation site. H2 is a homogeneous brown horizon of 17–20 cm thickness that shows similarities with a plow layer, although the abrupt lower boundary has fainted, due to an intense bioturbation. The combined thickness of H1 and H2 is unusually thick with respect to the depth and thickness of the eluvial horizon (H3) and the soil profile in general. This may suggest that H1 and possible part of H2 have developed in exogenic material. The site is located on the foot slope of an extended NW facing slope of the Tertiary inlier Kluisbergen. The colluvial input may have raised the soil with as much as 30–40 cm as a result of the intensive land-use that the site has known in the late Iron Age to early Roman period.

The granulometric difference between H1-H2 and H3-H4 is rather limited. This is possible if the colluvial input occurred over short distances and originates from similar pedological context. A slight increase in the silt content from 60 cm and further downwards in the reference profile corresponds to the border between H4 and H5. This corresponds to the buried surface of the Palaeolithic site. Considering that coherent soil development is present above this depth, it suggests that H3–4 has developed in exogenic material as well, but of a much older age than that of H1 and partly H2. In thin sections (cf 4.4) this burial material was described as heterogeneous, including angular sand grains and pseudo aggregates. At the same time the archaeological site remains relatively well preserved, which seems to exclude landslides or similar forms

Table 1
Description of the main soil horizons at the site of Ruien.

Horizon	Depth (cm)	Horizon symbol	Concise horizon description
H1	0–28	Ap	Present day plow layer; dark gray 10 YR 4/1 (slightly moist); sandy loam; granular; very friable; common very fine roots; abrupt smooth boundary
H2	28–45	Bh	Biological active horizon with humus accumulation; brown 10 YR 5/3 (moist); sandy loam; friable; few very fine roots; gradual slightly wavy boundary
H3	45–68	Eg	Slightly bleached horizon; brown to pale brown 10 YR 5.5/3 (moist); many coarse to very coarse distinct light gray 10 YR 7/2 and few medium prominent brown 7,5 YR 4/4 (moist) oximorphic mottles; sandy loam (8–10% clay); friable; clear slightly wavy boundary
H4	68–82	Bt	Slightly with iron and clay enriched horizon; yellowish brown 10 YR 5/4 (moist); sandy loam (12–14% clay); firm
H5	82–90	Au	

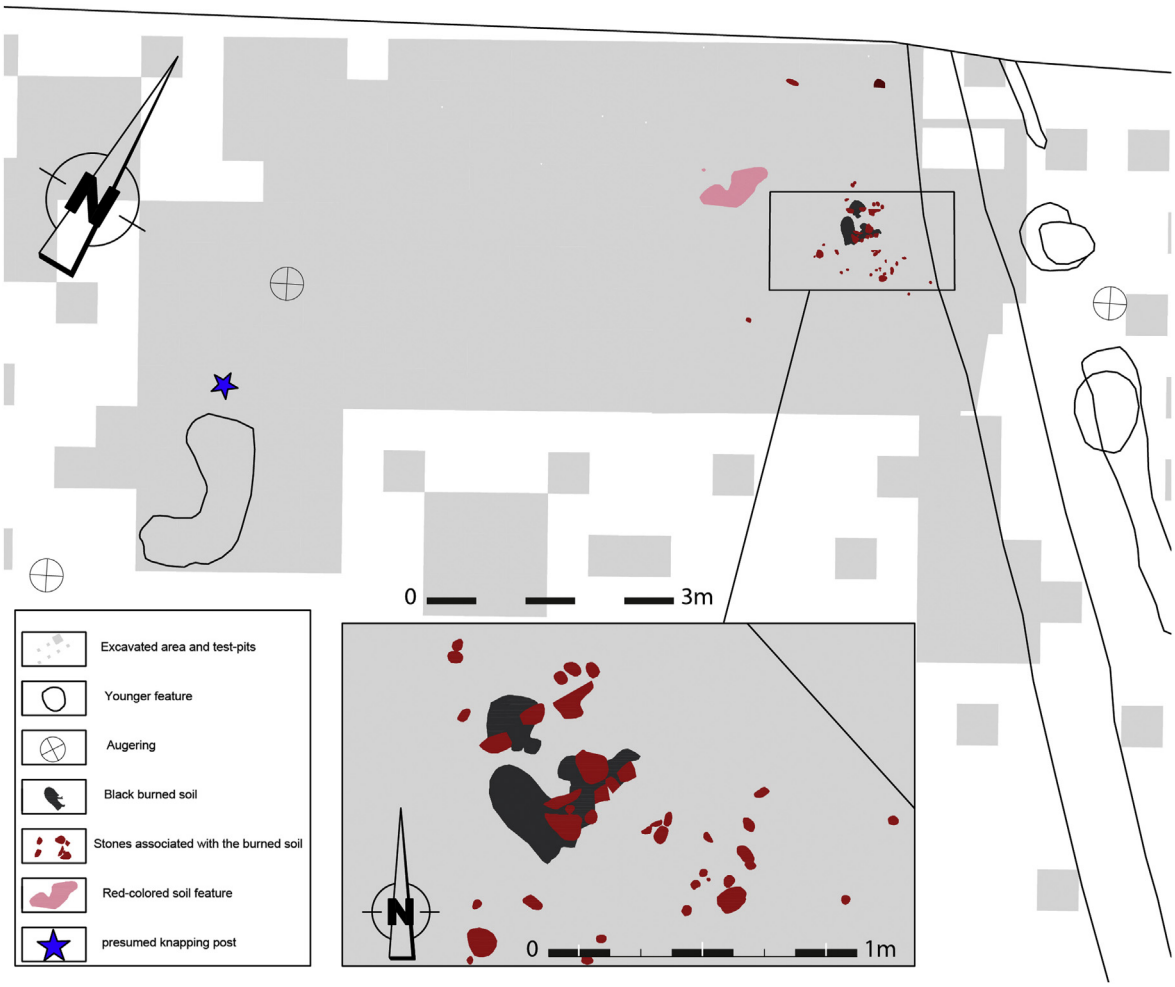


Fig. 5. Detailed excavation plan of the prehistoric sector at Ruien "Rosalinde", with close-up of the area with the remains of a stone-structured hearth.

of high energy soil movements. Colluvial transportation along a slope where the vegetation was partly or possibly completely destroyed by the rapid drop in temperature regime is on the other hand very well possible. The pseudo aggregates can have been transported in frozen conditions, either with the melt water or saltated with the wind. Small scale eolian input is not excluded, but drift sands are generally well sorted and (sub)rounded.

4.2. Archaeological analyses

The Palaeolithic finds, consisting of two features and a small lithic assemblage, occur in a thin find-layer situated at the boundary between the soil horizons H4 and H5 (Fig. 4). Compared to other prehistoric sites in the Scheldt basin (Crombé, 1998), the vertical distribution of the lithic artifacts at Ruien is very restricted, indicating limited bioturbation of the original occupation level. Ca. 80% of all artifacts is situated in a layer of 1–2 cm; the maximum vertical distribution attains 4 cm, a few exception aside. The tight stratigraphical association between the artifacts and both features (Fig. 4), one of which has been radiocarbon dated, argues for their contemporaneity.

4.2.1. Anthropogenic features

A first feature consists of a small cluster of sandstone fragments, found in an area of ca. 1 × 1 m in the eastern sector of the excavation (Fig. 5). Most sandstones are rather flat and present traces of a red coloring on their upper side, clearly related to heating (cf 4.5). Part of this sandstone cluster overlaps with a dark grayish ash layer underlying the stones (Figs. 4 and 5) and measuring ca. 0.5 m in diameter. The total absence of charcoal fragments within this layer indicates that only the finest fraction of the fire fuel could percolate between the sandstone fragments. Most likely these are the remains of a badly preserved stone-structured hearth. The scattered sandstones found to the south might reflect either deliberate removal (cleaning activities) or accidental disturbance of part of this hearth. However it cannot be fully excluded that this small sandstone configuration rather represents the remains of an area where cooking stones were heated. Yet, in that case we would expect the sandstones to be burned entirely and not along just one side. In addition the preference for rather thin and flat sandstone fragments rather advocates an interpretation as hearth.

Ca. 1.5 m to the west of this stone-hearth an irregular ca. 4 cm thick red-colored patch was excavated, measuring 90 × 40 cm (Fig. 6).

4.2.2. Lithic industry

Altogether the prehistoric level yielded 3496 artifacts and 58 frost flakes (Table 2) (Fig. 7). The assemblage is largely dominated by small items, i.e. chips (N = 2640; 75.5%) and undetermined fragments <1 cm (N = 182; ca. 5%). The artifacts have an overall fresh aspect; hardly 2% displays traces of posterior frost damaging,

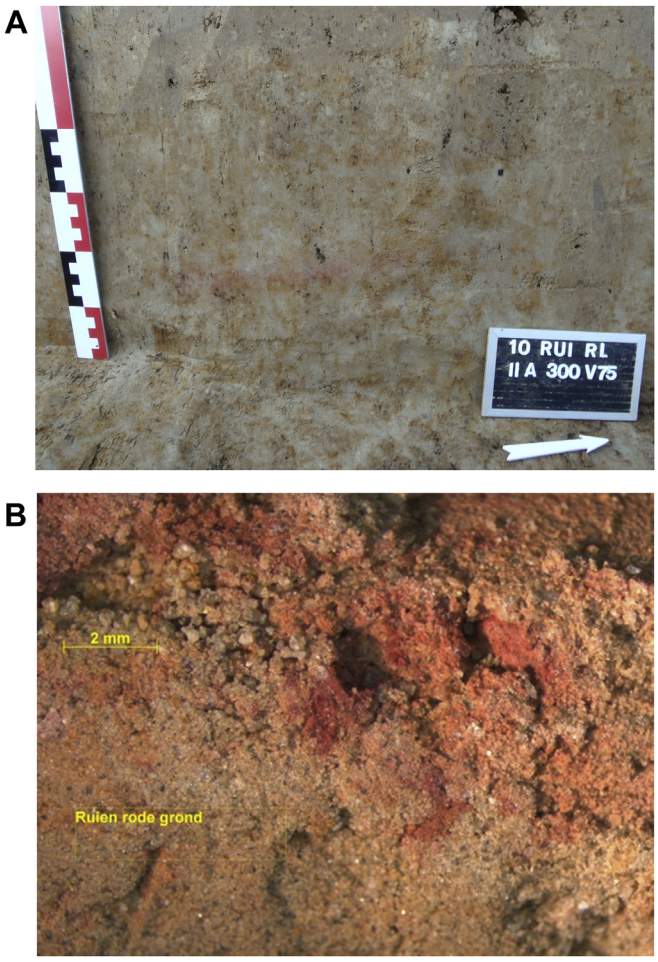


Fig. 6. (A) Photo of the red-colored feature in situ (photo SOLVA); (B) **m**Microscopic image (Zeiss Discovery V8, x 10 enlargement; RCE) of a part of the red-colored feature. From the microscopic image, it can be observed that the red-coloring is not allochtonous material but is local material that has colored red. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

while posterior patina (generally of white blue color) occurs on just 8% of the assemblage. Heat damaging is limited to less than 1%.

The majority of artifacts ($N = 510$; ca. 70%) are made on a moderately coarse-grained flint of dark grayish color with small light grayish inclusions. Judging by its rolled and weathered cortex and the frequent occurrence of anterior frost fractures, the latter generally indicated by a brownish patina, this flint clearly originates from a secondary outcrop. The presence of numerous artifacts with cortical remnants ($N = 254$; ca. 50%), among which ca. 25% artifacts with cortex covering more than half of the dorsal face, indicates that this flint was brought to the site as complete nodules and/or large frost fragments. A local or regional origin seems very likely, either from nearby terraces of the Scheldt or from the southern chalk area of Belgium (Hainault) or northern France (Picardie) at distances of 30–50 km (Fig. 7(1)). A second important grayish flint variety yielded 132 artifacts (ca. 18%) and possesses very specific characteristics, which exclude a local/regional origin. Its very coarse sometimes micaceous grain and weathered non-chalky surface resembles a raw material found in the central part of Belgium, i.e. in the vicinity of Tienen situated ca. 100 km east of the site (Fig. 7(2)). This flint variety also yielded numerous artifacts with cortical remains (ca. 40%), with ca. 27% covering more than half of the dorsal surface. Just one core was found, indicating that all artifacts most likely belong to a single reduction sequence. The remaining flint types were only knapped incidentally. Ca. 7% of the artifacts ($N = 52$) are made of a fine-grained grayish flint with beige banded zones, while 1% (and ca. 62 chips) were produced from a beige to yellow translucent flint which resembles chalcedony (oral communication Jos Deeben). Outcrops of this flint are known e.g. in the Muffendorf area of the German Rhineland some 250 km away (Crombé et al., 2014) (Fig. 7(5)). Given the few artifacts and the absence of a core it may be assumed that this presumed exotic raw material was brought to the site in a semi-finished way, either as a blank or as a tool. Alternatively it may have been knapped in an area beyond the excavated zone. Another exotic raw material was found on just one artifact. A large tanged artifact was made on a coarse-grained white colored chert, resembling certain kinds of flint from the Moselle valley, e.g. "Chaille du Muschelkalk" (Spier, 2000), at ca. 250 km southeast from the site (Fig. 7(4)). Finally a few artifacts seem to be made in a light grayish flint with white inclusions typical of the Belgian Hesbaye area (ca. 120–130 km; Fig. 7(3)). In conclusion, the exotic flint varieties found at the site all originate from areas situated to the east of the site at distances ranging between ca. 100 and ca. 250 km.

Typologically the lithic assemblage is dominated by unretouched waste products, such as chips and artifacts <1 cm (ca. 80%), flakes (ca. 10%), blade(let)s (ca. 6%), cores (ca. 0.5%) and rejuvenation artifacts (ca. 0.5%). With just 23 specimens, retouched tools are hardly present (Table 2).

The knapping clearly was oriented mainly towards the production of short, narrow and thin bladelets (Fig. 8 (11–15)), with average dimensions of 29.54 mm length, 9.77 mm width and 2.6 mm thickness. Ca. 70% of all bladelets have a width between 6 and 11 mm and ca. 80% is hardly 1–3 mm thick (Fig. 9). The length ranges in ca. 85% between 16 and 40 mm. Although complete blades having a length of >50 mm are almost totally absent (5 complete specimens), the length of some fragments (ca. 13 sp.) and at least three crested blades demonstrate the knapping of a limited series of blades between 50 and 60 mm long and occasionally even longer (Fig. 8(4–6)). A detailed morpho-technological analysis (Fig. 10) shows that the majority of bladelets have a triangular (ca. 40%), trapezoidal (ca. 23%) or irregular (ca. 23%) cross-section. Their longitudinal curvature is predominantly straight (ca. 41%) followed by slightly concave (ca. 22%) and slightly torqued (ca. 14%). Many bladelets are rather regular displaying parallel to (sub)parallel edges (ca. 38%) and dorsal ridges (ca. 47%) (Fig. 10). Bladelets with convergent edges (ca. 29%) and one central rib (ca. 31%) are also very frequent. Knapping accidents are rather limited (ca. 21%) resulting mainly in hinge fractures (ca. 16%) and only a few *languette* (ca. 4%) and plunged fractures (ca. 1%). Butts are mostly very thin (1–2 mm) ranging from linear (ca. 44%) to pointed (ca. 20%); bruised butts also occur regularly (ca. 11%). Percussion bulbs are present on almost half of the bladelets, though never in a well-pronounced way. A clear lip has only been attested on ca. 10% of the bladelets, while undulations (ca. 71%), radial striations (ca. 35%) and splinters (ca. 40%) are very frequent. Among the latter butt splinters (ca. 30%) clearly prevail with respect to bulb splinters (ca. 10%). The dorsal face of the bladelets generally displays remains of core edge rejuvenation (ca. 52%) either by retouching and/or abrasion. The number of dorsal negatives is generally low, between 1 and 3 negatives (ca. 76%). The percussion direction of these dorsal negatives is mostly unidirectional (ca. 76%), while bidirectional negatives occur in just ca. 10%.

Among the cores ($N = 18$, among which 8 undetermined fragments), however, specimens with one (4 spec.) and two crossed or opposed platforms (resp. 2 and 3 spec.) are almost equally represented (Fig. 8(1–3)). This difference in percussion direction between bladelets and cores clearly points to the fact that the

Table 2
Typological inventory of the lithic assemblage.

Artifact type	*N*	%
Cores	18	0.51
Rejuvenation artifacts	21	0.60
Flakes	219	6.26
Flake fragments	123	3.52
Blade(let)s	82	2.35
Blade(let)s proximal	51	1.46
Blade(let)s medial	16	0.46
Blade(let)s distal	53	1.52
Undetermined fragment	42	1.20
Chips	2640	75.51
Artifact fragments <1 cm	182	5.21
Debris	24	0.69
Borers	3	0.09
Modified bladelets	4	0.11
Modified flakes	8	0.23
Krukowski microburins	2	0.06
Armatures	7	0.20
Burin	1	0.03
	3496	**100.00**
Frost flakes	58	

knapping was organized mainly unidirectionally even on cores with two striking platforms. Cores most likely were re-oriented for each knapping phase. Most cores have a rather sharp striking angle ranging between a minimum of 45° and a maximum of 100°, with a mean of 71°. Most angles are situated between 45° and 85°. Platforms consist of old frost facets ($N = 7$) and are often slightly facetted ($N = 9$). Core edges are frequently either trimmed ($N = 4$), abraded ($N = 3$) or both ($N = 1$), although less on the second platform. Negatives on the exploitation table(s) belong mainly to bladelets ($N = 7$) and to a lesser extent to flakes ($N = 5$). The latter seem to correspond to an opportunistic exploitation before discard of the blade/bladelet cores. The extent of the knapping is very variable but mainly is limited to ¼ ($N = 5$) or ¾ ($N = 4$) of the core contour, both facial and frontal. On all cores numerous hinge fractures have been observed, which might be the reason for their discard. Except for 3 specimens, all cores are made on local/regional flint nodules. The presence of numerous rejuvenation artifacts, among which 14 crested blades (+1 used as tool) and 7 lateral flakes (Fig. 8(6,16,20)), indicate frequent adjustments and reorientation of the knapping. Except one, all crested blades present unilateral preparation, sometimes combined with a natural frost facet. One crested blade even is formed by two frost negatives, indicating the use of natural edges at the start of the bladelet production. The 7 lateral flakes, perpendicular to the axis of the exploitation table, prove regular rejuvenation of the edge of the striking platform, probably in order to keep the edge angle sharp enough and/or manage the lateral and longitudinal convexities of the table.

Half of the small toolkit ($N = 23$) consists of simply retouched flakes ($N = 8$) and bladelets ($N = 4$). However, the intentional character of this retouch, which is always partial and limited, needs to be questioned. It is not unlikely that they are related to the knapping process and are thus accidentally produced. There are however two exceptions: a flake with continuous retouches on the distal edge (Fig. 8(17)) and a proximal fragment of a backed bladelet. Besides these simply retouched artifacts there are 3 borers (Fig. 8(19)), one of which was produced on a crested blade (Fig. 8(20)), 1 burin on truncation (Fig. 8(18)), and 7 armatures (Fig. 8(7–10, 21)). Except 2, the latter are all heavily fragmented hindering a further typological determination. All armatures, except one, are microlithic and made on very small (5–6 mm) and straight bladelets. One complete armature can be determined as a small backed bladelet provided with a small distal truncation (Fig. 8(9)). Two fragments clearly belong to unilaterally backed

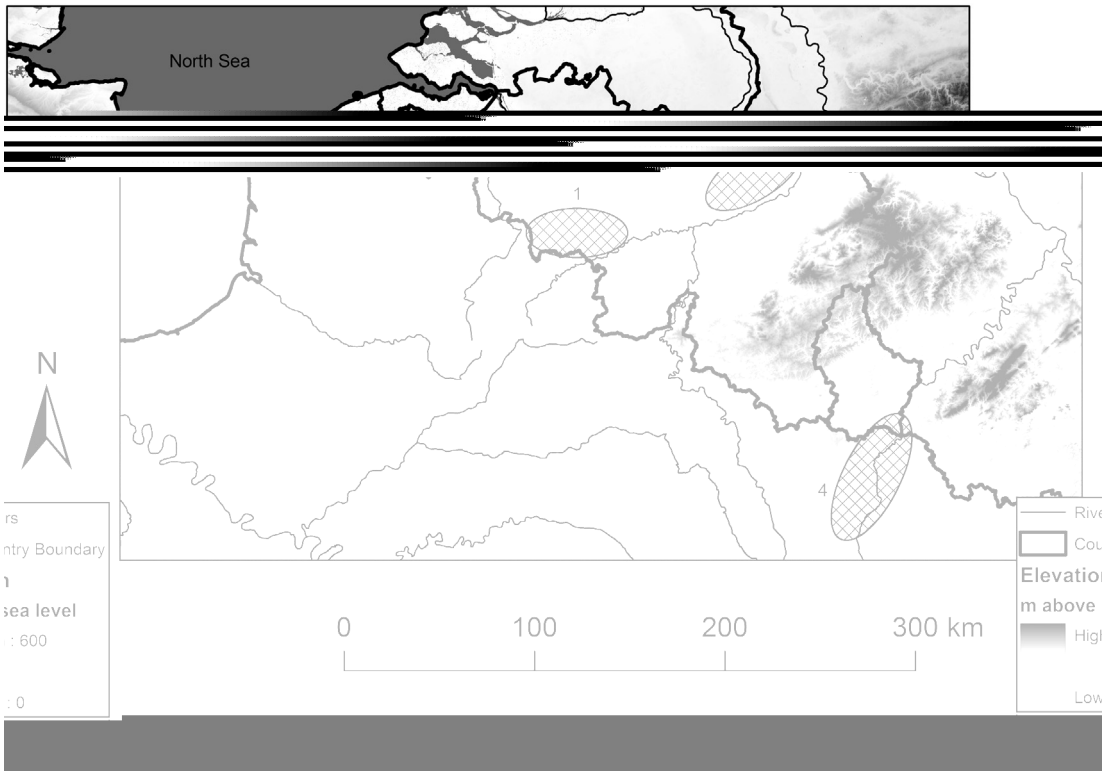


Fig. 7. Map of the Rhine-Meuse-Scheldt area indicating the outcrop areas of flint varieties transported to the site of Ruien "Rosalinde".

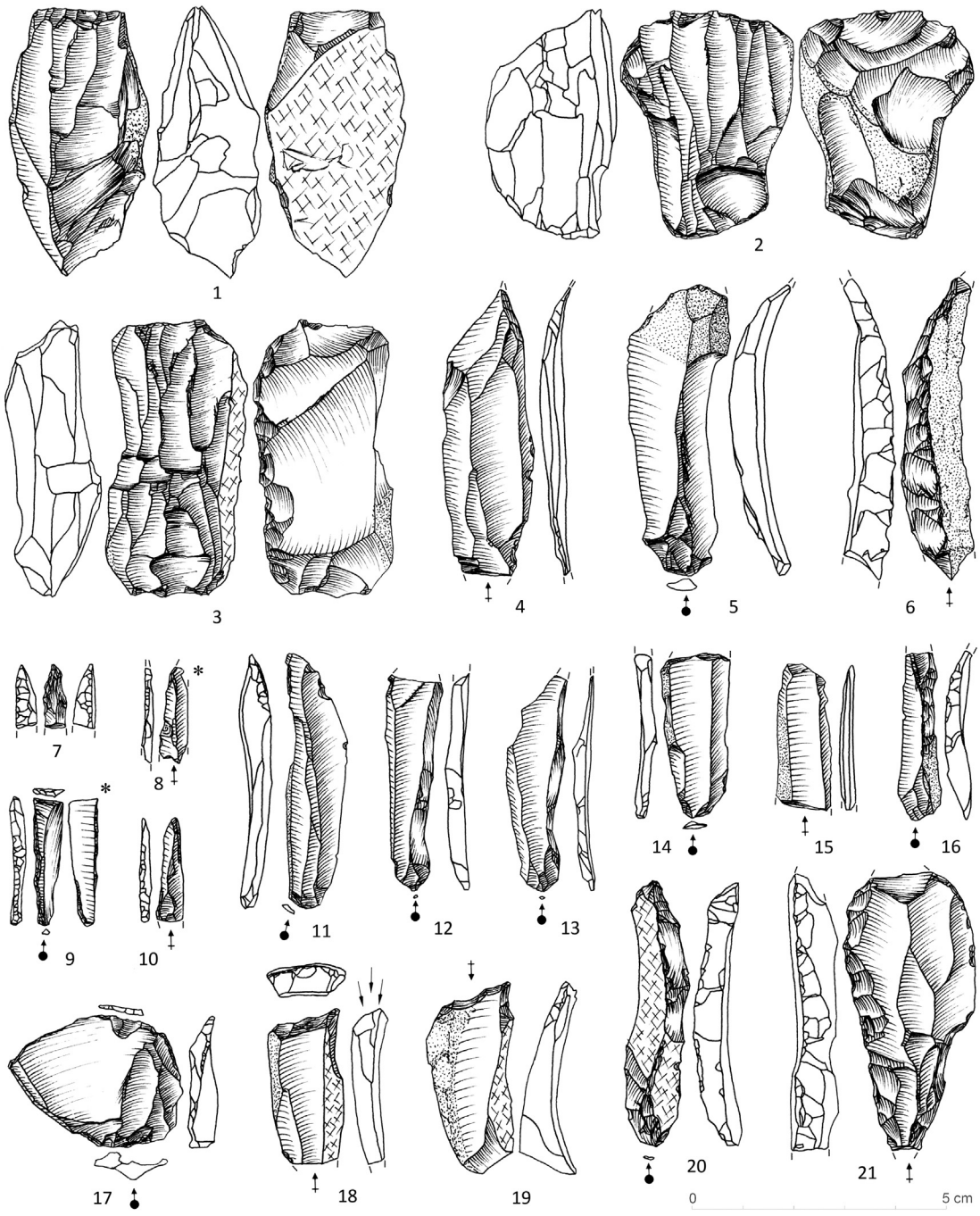


Fig. 8. Lithic artifacts from the site of Ruien "Rosalinde".

armatures (Fig. 8(8 and 10)). Two small Krukowski microburins are most likely related to the production of armatures on the site. Last but not least a long and heavy tool made on an exotic flint possibly from the Moselle region should be mentioned. This unique artifact (Fig. 8(21)) typologically differs considerably from all other artifacts and tools within the assemblage. Broken at its two ends, it is intensively retouched along its entire left side and the proximal part of the right side by means of steep to oblique dorsal retouches. It is however not clear whether this was meant to produce a massive borer or a kind of tanged tool. As a matter of fact this artifact closely resembles the tanged points and (Wehlen)scrapers found in context of the *Federmesser* and Bromme Cultures of southern Scandinavia (Riede, 2008; pers. communication). However, the enormous distance (>600 km) between the core territory of the Bromme Culture, situated in northern Germany, Denmark and Scania, and the Belgian Scheldt valley makes it rather unlikely that it really concerns a Bromme tool. Yet it should be mentioned that similar tanged points or scrapers have been reported from *Federmesser* sites in the southern Netherlands (Jos Deeben, pers. communication).

4.2.3. Preliminary spatial analysis

The horizontal distribution of the anthropogenic features and lithic artifacts displays some very clear patterns which inform us about the general spatial organization of this small camp-site (Fig. 11). A first distinct activity area, partially perturbed by a

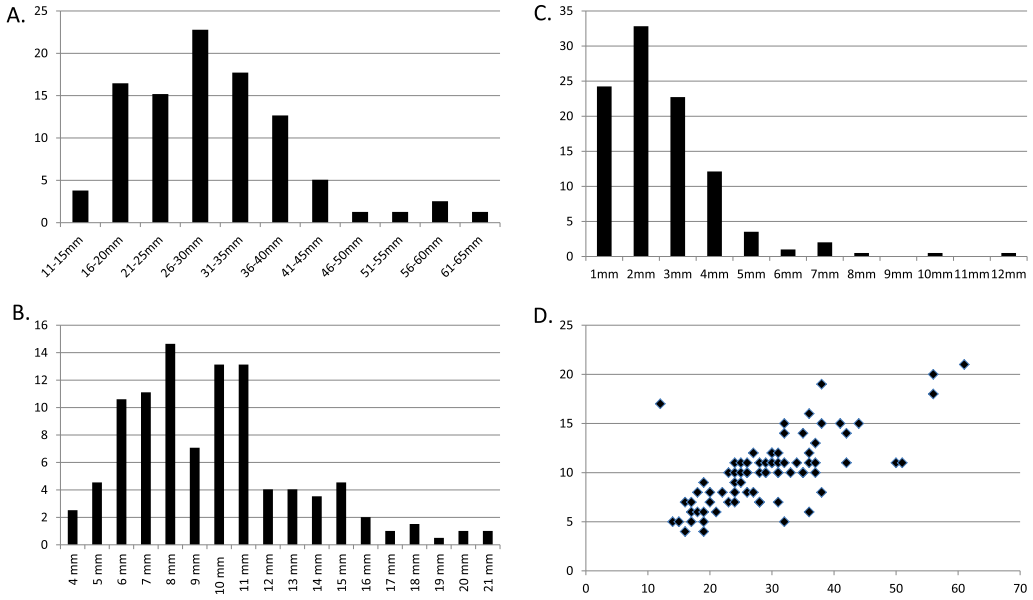


Fig. 9. Bladelet dimensions (%); A. length classes ($N = 79$); B. width ($N = 198$); C. thickness ($N = 198$); D. length/width ratio ($N = 79$).

tree-fall feature, is situated ca. 8 m to the southwest of the stone-hearth. Here a small but very dense cluster, covering hardly 1 m^2, occurs, which contains artifacts from all phases of core reduction related mainly to the knapping of local/regional flint (cf. 4.2.2). With 13 cores, 12 rejuvenation products and only simply retouched "tools" (cf 4.2.2) this small cluster can be characterized as a specialized knapping post. A second, less dense knapping post is situated immediately southeast of the stone-hearth, in a small zone

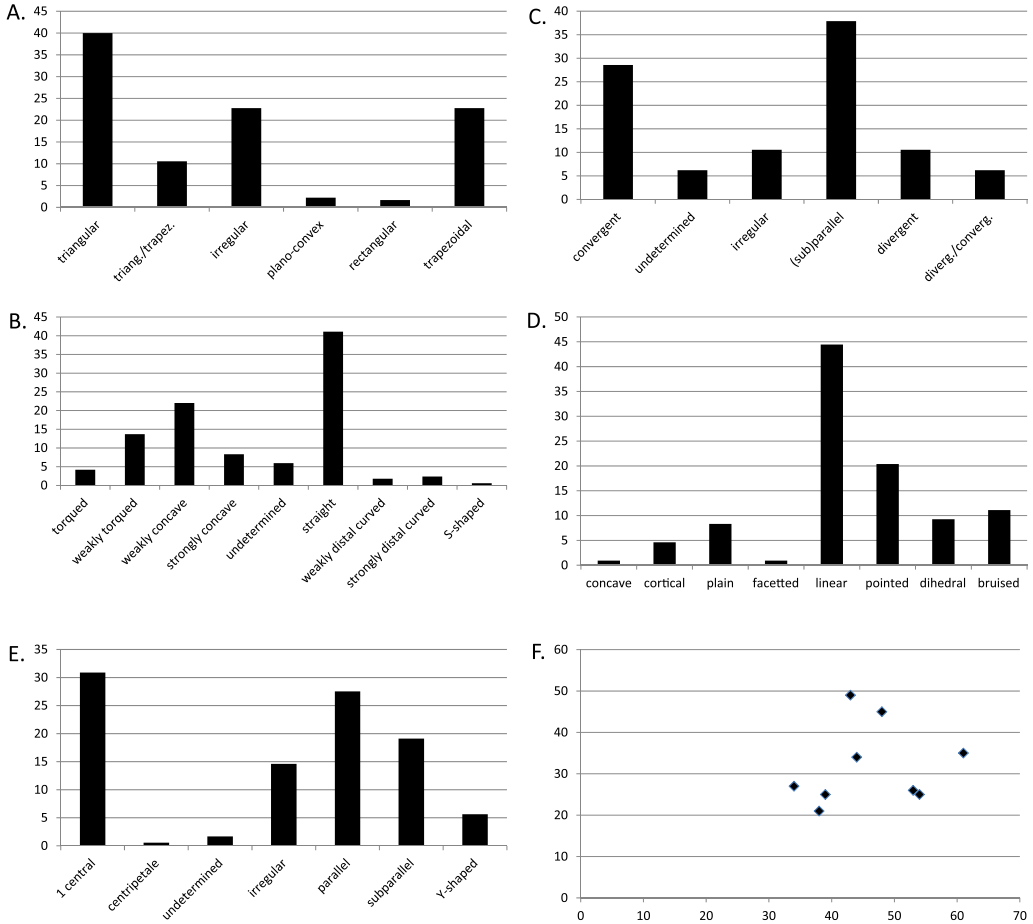


Fig. 10. Frequencies (%) of different morpho-technological attributes from bladelets. A. cross-section ($N = 180$); B. longitudinal curvature ($N = 168$); C. lateral edges ($N = 161$); D. butt type ($N = 108$); E. dorsal ridges ($N = 178$): F. core dimensions (length/width ratio in mm).

Table 3
List of radiocarbon dates obtained on the stone-built hearth from Ruien.

Sample code	Lab code	BP date	68.2% Probability	95.4% Probability
RL611	RICH-20143	10,962 ± 48	10910BC–10780BC	11030BC–10760BC
RL611	RICH-20142	10,843 ± 50	10805BC–10745BC	10860BC–10730BC

with scattered sandstones probably initially belonging to the hearth (dump zone?). The artifacts from this cluster mainly belong to the second flint type, assumed to originate from central Belgium. The presence of four broken armatures and two Krukowski microburins might indicate retooling of the hunting equipment. The third and smallest knapping post is situated north of the stone-hearth and exclusively consists of artifacts in chalcedony. Among the ca. 62 chips several clearly are related to resharpening of a ca. 0.5 cm thick tool provided with a steep retouch. No artifact clusters, however, were found in spatial connection with the red-colored patch.

4.3. Radiocarbon analysis

The ^{14}C date (RICH-20143) obtained on the sample pre-treated with AAA is the most accurate as exogenous carbonates and humic acids were removed (Table 3). It situates the stone-hearth from which the sample was retrieved between ca. 11,030 and 10,760 cal BC, which corresponds with the transition from Allerød to YD. The dating of the sample pre-treated with HCl (RICH-20142) resulted in a younger date indicating the presence of humic acids. However, RICH-20143 and RICH-20142 are statistically not different (χ^2-Test: df = 1 T = 2.9 (5% 3.8)).

4.4. Analysis of the red-colored feature

4.4.1. Micromorphology

The groundmass consists of badly sorted sand with angular fragments of fine gravel that contains (often displaced) limpid clay coatings. Several types of iron oxides occur in the groundmass:

- Throughout the groundmass rounded nodules occur that mostly fall in the 100–200 micron range. They commonly have a brown-red core with a yellowish to green tinted surface. They are probably iron oxide grains with a glauconite coating (Fig. 12A).
- A few rounded nodules in the same size range as the ones mentioned above are opaque black, and show some reflectance with oblique incident light (OIL). They are tentatively identified as concretions of manganese oxides – but magnetite or wüstite grains cannot be excluded (Fig. 12B).
- The groundmass is locally cemented with iron oxides that occur as coatings around the sand grains, and that sometimes fill the whole pore space. It is remarkable that their occurrence is irregular, with completely cemented domains occurring immediately next to domains with no iron oxides coatings whatsoever. The color of the coatings varies, grading from brown or reddish brown to bright red that tends towards purple – sometimes within one cemented domain. These differences probably represent differences in the iron oxide mineralogy (Fig. 12B), e.g. between goethite (brown) and hematite (reddish to purple).

The deposit is interpreted as displaced material (colluvium, solifluction debris or anthropogenically displaced material) that contains gravel, partially weathered glauconite and relict pedo-features like clay coatings and iron precipitates.

Part of the iron oxides have been transformed from goethite to hematite by fires lit on top of the soil. Temperatures between 200 and 400° centigrade should be sufficient to produce this effect (Schwertmann and Taylor, 1989). There are no indications that ochre or other reddish material was transported to the site on purpose. The reddish color rather seems to be an effect of fire on this location.

4.4.2. XRD results

The only identified mineral within the red-colored soil is quartz. There are some reflections that could be attributed to the presence of wüstite, FeO (Fig. 13). There are no indications for the presence of hematite.

4.4.3. XRF results

4.4.3.1. Box P1. From Table 4 and Fig. 14A it appears that in the brown-gray top layer, Fe_2O_3, CaO and Rb are significantly lower than in the underlying sediments. Furthermore it contains more SiO_2, and is therefore probably more sandy than the deeper layers.

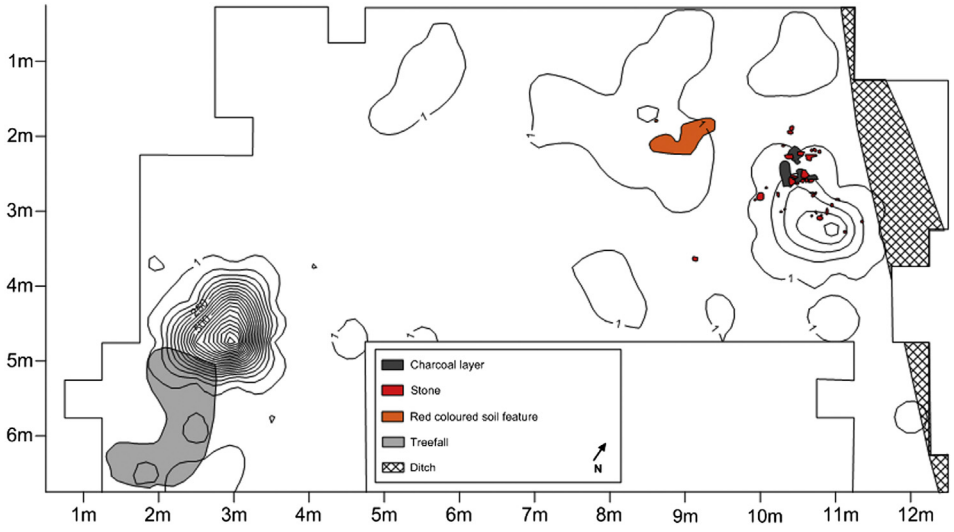


Fig. 11. Contour map of the distribution of lithic artifacts at Ruien "Rosalinde"; contour interval 50 artifacts.

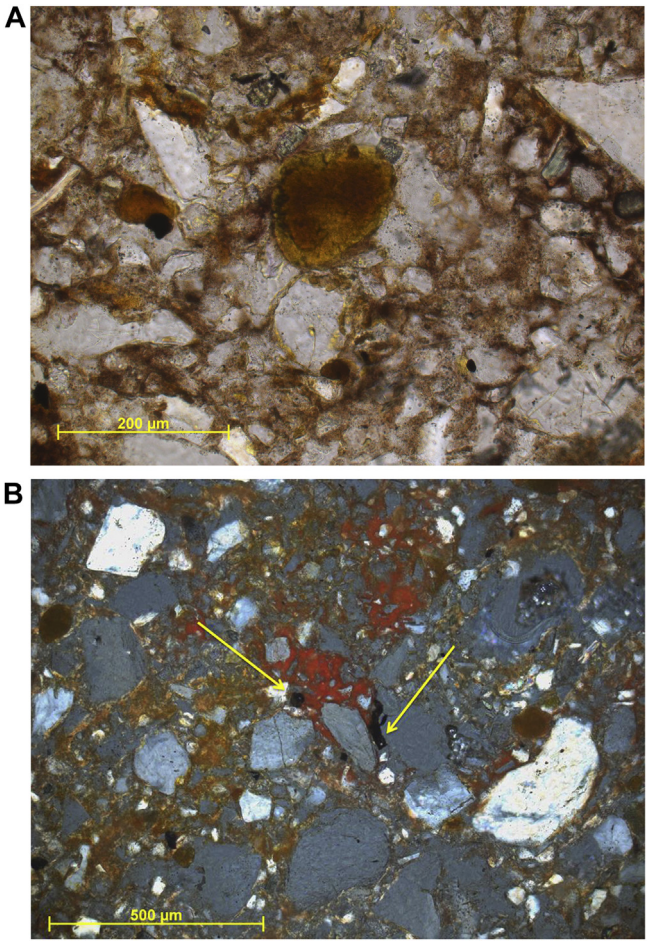


Fig. 12. (A) Microscope image of a glauconite coated iron oxide grain in a matrix of unsorted subangular and angular quartz grains (B) Crossed nicols microscope image of several phases of iron (hydr)oxides and opaque phases (arrows), possible wüstite associated with the ochre colored phase, possible heamatite. Note that the boundary between the ochre colored phase and the light brown ironhydroxide phase is very diffuse. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

CaO, P_2O_5, Al_2O_3, TiO_2, Fe_2O_3 and Zr, Sr and Ba show more or less the opposite trend as SiO_2 does. As these elements are mainly present in clay minerals, it can be concluded that the top contains more quartz and has a higher sand content. No significant change in chemical signal is observed at the level of the prehistoric find-layer. The Zr and P_2O_5 content at the top of the latter at 13.5 cm are somewhat higher than average.

4.4.3.2. Box P2. In box P2 the same chemical trends are recognizable as in box P1 (Table 5; Fig. 14B). Higher SiO_2 content in the upper part and higher content of clay related elements in the lower part. Again an increase in Zr is found at the top of the prehistoric find-layer. There is, however, no increase in Fe_2O_3 content or any variation in other elements within the level of the red-colored feature.

4.4.3.3. Box P3. Also in box P3 the same trends can be observed as in the other boxes (Table 6; Fig. 14C). Clay related elements are higher in the lower part of the box. No clear lithochemical boundary is visible at the presumed prehistoric surface.

In all three boxes, the top has the highest SiO_2 content and the content of clay related elements such as Al_2O_3, Rb and K_2O are lower. In addition the total amount of oxides measured at the top of the surface is higher than in the lower part. This can be explained by the moist field conditions the boxes were in when measured. Water will absorb especially the x-rays of lower energy from the light elements (Al to Cl). The more clayey lower part of the boxes retain somewhat more moisture, leading to lower light element values and as a result higher balance values. No attempt was made to correct for this difference, as it will only affect the light elements and would not profoundly change the observed trends.

The observed difference in lithology between the upper and lower parts of the boxes is also reflected in the chemical composition (Fig. 15). In the decalcified soils Rb and Sr are mainly present in clay minerals and feldspars. The variation of both elements in the lower level is higher than in the upper level, indicating a larger variation in mineralogy in the former. The zircon (Zr) content is the highest at the boundary between the upper and the lower level in box 1 and 3, coinciding with the level of the prehistoric find-layer. Zr occurs mainly in the heavy mineral zircon, ($ZrSiO_4$). An enrichment of Zr can be explained by wind sorting, whereby the heavier zircon minerals lag behind and the lighter quartz sand grains are blown away (Zonneveld, 1946; Shepard et al., 1961). This would indicate that the prehistoric surface was not covered by vegetation for some time resulting in the enrichment of zircon. However, the zircon enrichment is not found within the red-colored feature (P2), which may be due to local disturbance of the surface, possibly caused by fire.

The variation in Fe_2O_3 (Fig. 16) is relatively much larger than the variation in the clay related elements such as Sr. Iron is present in many phases in this sediment; as ironhydroxides coating around the sand grains, in clay minerals and in the mineral glauconite. Fig. 16 indicates that the iron content is much higher in the lower level than in the sandier upper level. Most likely the coarser grain size of the upper level and therefore the smaller surface area is responsible. In addition pedogenetic processes, such as mobilization by humic acid complexes of iron in the upper layer and precipitation could have enhanced the iron content in the lower level of the boxes. However, no clear soil profile is observed. The absence of iron enriched layers indicates that no permanent stagnant groundwater level exists at this location. Furthermore, this also indicates that seepage of reduced groundwater does not occur. The patchiness of the soil profile is most likely caused by hydromorphic conditions: the presence of organic matter can lead to the mobilization of iron during wet periods and precipitation of iron hydroxides when the soil is dry. The drainage of the upper layer is better, due to its coarser structure. Therefore remobilization of iron will occur more often and longer in the lower layer, explaining also the larger variation in iron content at the lower level.

The iron content of the red colored feature is similar to the other samples from the lower levels. This also holds for the other measured elements (Fig. 16). The red feature, however, seems persistent to the hydromorphic conditions that caused the patchiness of the soil. This indicates that the iron phase in the red-colored feature is more resistant to periodic reducing conditions than the surrounding soil. One of such phases more resistant towards hydromorphic conditions is hematite (Roden, 2003). Hematite does only form during tropical climatic conditions (laterites) (Schwertmann, 2008, 367). However, hematite can also be formed by heating goethite and ironhydroxides (Gialanella et al., 2010) at 300–500° C. In tropical soils during wildfires ironhydroxides can be transformed into maghemite, another form of hematite (Schwertmann, 2008, 368), especially under a restricted oxygen supply. So, the red-coloring at Ruien most likely is caused by transformation of available ironhydroxides into hematite or maghemite under influence of heat, either naturally or humanly induced. The presence of wüstite (FeO), shown in the XRD spectrum, might be an argument against a natural origin (wild fire), as wüstite may be formed by heating ironhydroxides under reducing

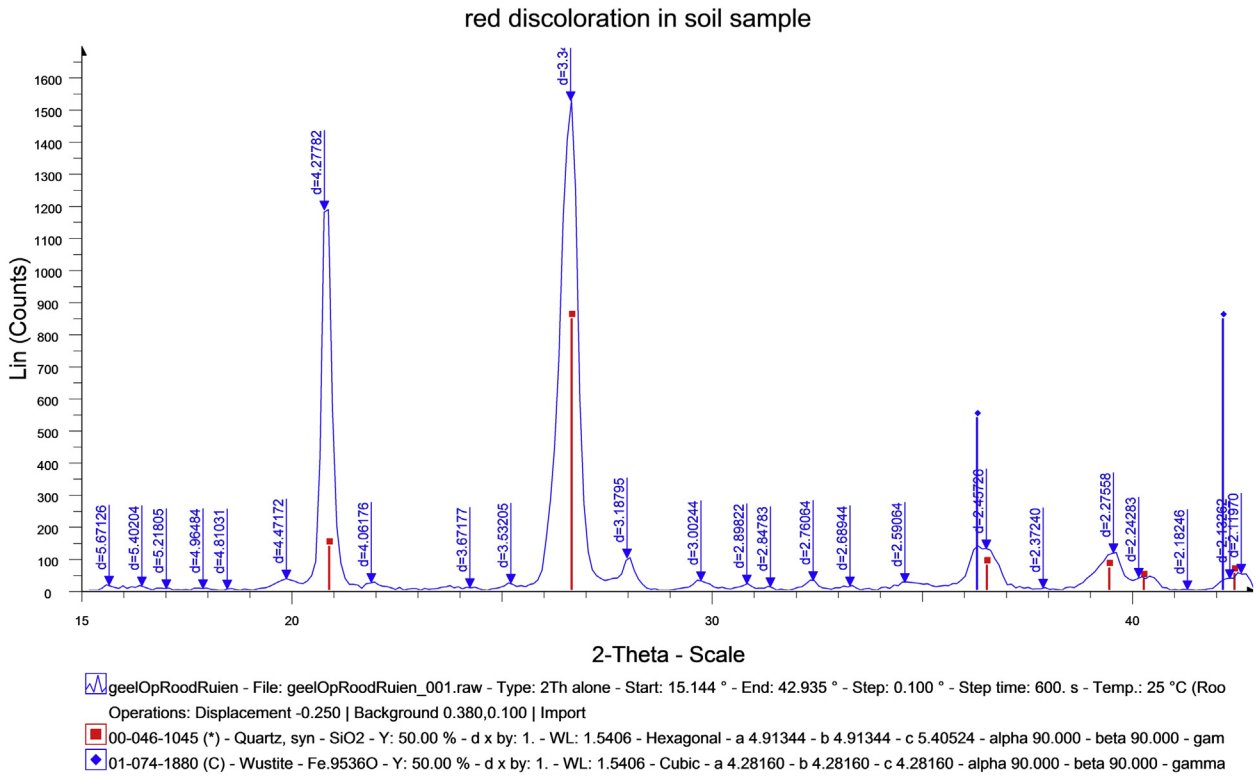


Fig. 13. XRD analysis of the red-colored feature. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

conditions (adding of charcoal) at temperatures higher than normally found in wild fires, i.e. exceeding 700° C (Campbell et al., 1997).

4.5. Analysis of hearth stones

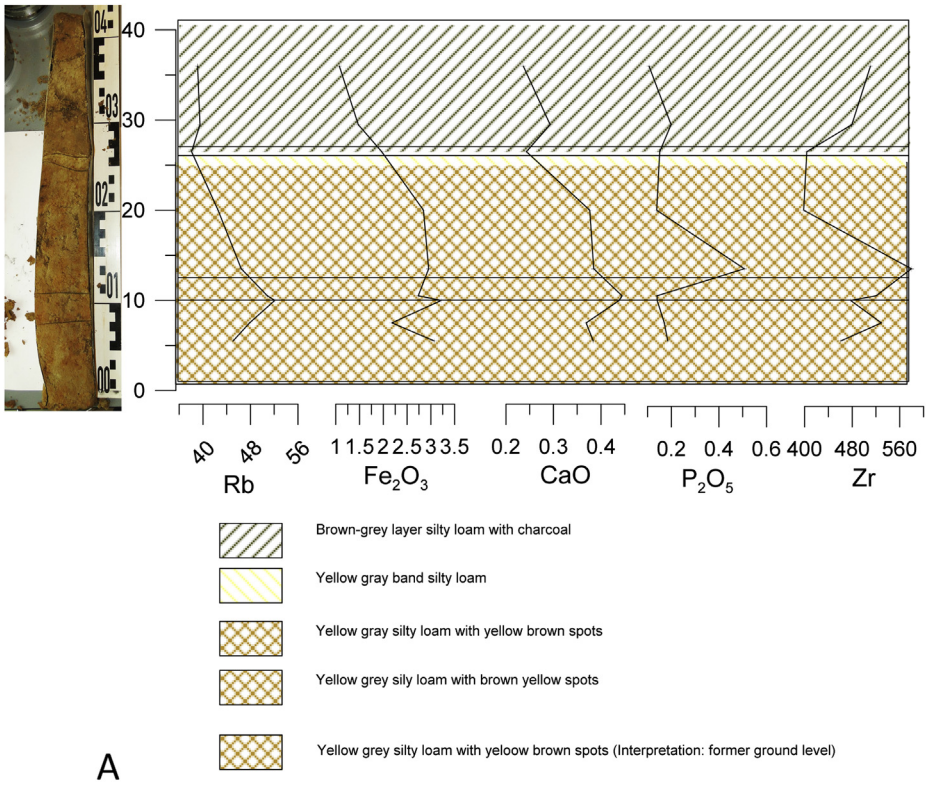
The hearth stones were identified as a brownish-red ferruginous sandstone and green glauconiferous sandstone. The ferruginous sandstone is known to occur in the Diest Formation (Cnudde et al., 2011), which can be found at the top of the nearby Kluisberg. Greenish glauconiferous sandstone, known as field stone, can occur at several levels within the Ieper Group which crops out at the flanks of the Kluisberg. Thus, both stone types are likely to have a local origin. The samples show a discoloration of the crust at only one side. This discoloration is intense red to pink in the ferruginous sandstone crust and reddish-pink in the glauconiferous sandstone crust (Fig. 17). This discoloration is caused by irreversible transitions of iron minerals in these crusts and indicates the probable cause of heating by fire at temperatures elevated above 250 °C up to 900 °C. In the ferruginous sandstone, this is marked by a transition of goethite to hematite, evidenced by XRD and DSC results, and a color transition of brownish-red to red (De Kock et al., submitted for publication). In the glauconiferous sandstones, this heating is marked by a brownish discoloration of the glauconite seen in thin section (Fig. 17), accompanied with the formation of free iron components as shown by DCB (De Kock et al. submitted for publication). Such discoloration and mineral transitions have been described for heating in laboratory environments by e.g. Chakrabarti et al. (1996) and Hajpal and Török (2004).

5. Discussion

The stratigraphical position of the described features and lithic artifacts, i.e. in a thin find-layer covered by 0.5 m of sandy-loam deposits mainly of colluvial origin, as well as the scarcity of frost altered artifacts (ca. 2%) allow us to assume a relatively rapid sealing of the site. Also the tight clustering of the smallest flint items (chips) and the limited bioturbation support this idea. However, refitting is necessary to provide certainty about the strict contemporaneity between the features and the different flint knapping areas. The fact that in each activity zone a different

Table 4
Major and trace element concentrations of box P1. Red colors indicate the highest values, white average values and green cells have the lowest values. Bal = balance: 100%-amount of oxides.

Distance from bottom	SiO_2	CaO	P_2O_5	K_2O	Al_2O_3	TiO_2	Fe_2O_3
	%	%	%	%	%	%	%
36	64	0.24	0.11	1.1	1.2	0.46	1.1
29,5	64	0.29	0.20	1.1	1.8	0.36	1.5
26,5	59	0.24	0.15	1.0	1.3	0.31	2.0
20	34	0.38	0.14	1.1	2.2	0.33	2.8
13,5	36	0.38	0.51	1.1	1.9	0.47	3.0
10,5	39	0.44	0.14	1.2	2.9	0.46	2.7
10	35	0.44	0.14	1.2	2.3	0.44	3.2
7,5	43	0.37	0.17	1.2	2.0	0.42	2.2
5,5	28	0.38	0.18	1.1	1.2	0.42	3.1
	MnO	Bal	Zr	Sr	Rb	Ba	
	%	%	mg/kg	mg/kg	mg/kg	mg/kg	
36	0.01	31	511	44	39	317	
29,5	0.02	31	480	46	39	335	
26,5	0.01	36	404	41	38	311	
20	0.01	59	398	37	43	301	
13,5	0.01	57	580	51	46	289	
10,5	0.01	53	520	51	51	316	
10	0.01	58	477	47	52	319	
7,5	0.01	50	529	52	48	290	
5,5	0.01	65	461	48	45	312	



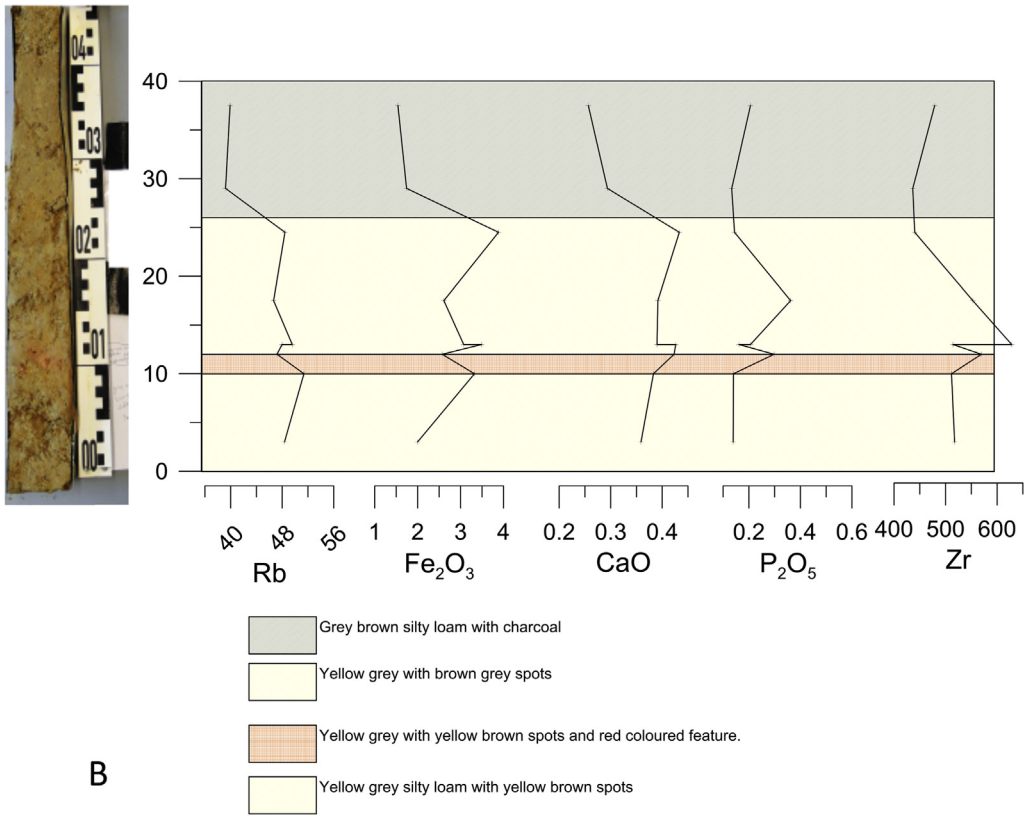


Fig. 14. Results of the chemical XRF analysis nearby the red-colored feature. Variations of Rb Fe_2O_3, CaO, P_2O_5 and Zr in box P1 (A), P2 (B) and P3 (C). Concentrations of oxides are in percent and of elements in ppm.

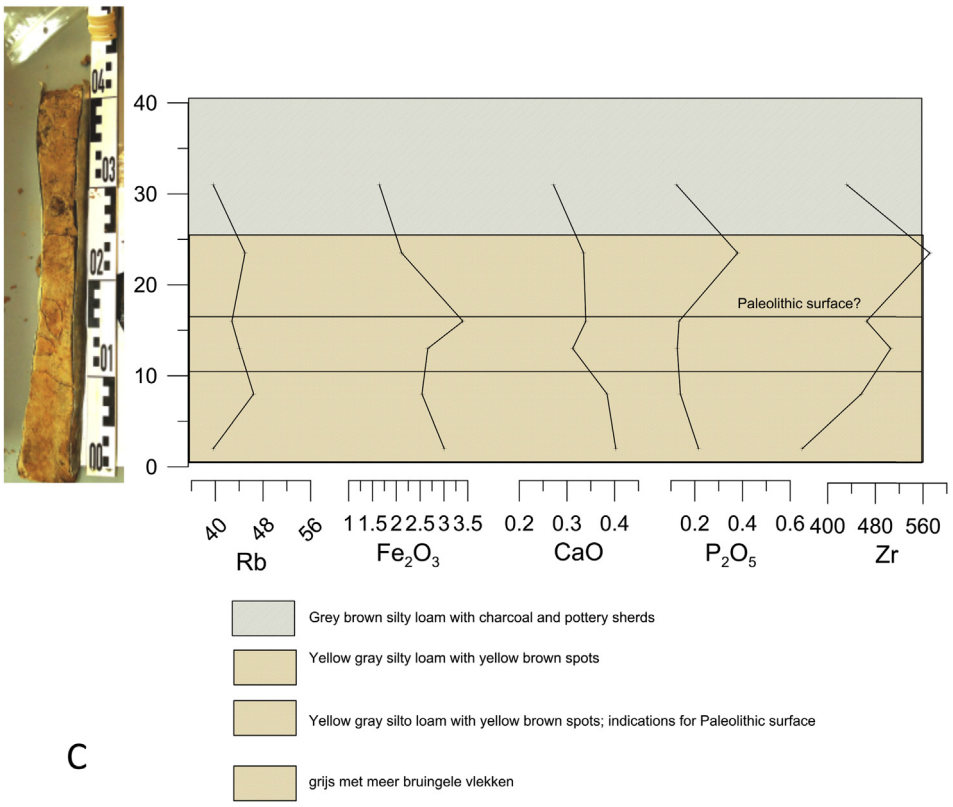


Fig. 14. (*continued*).

flint variety has been knapped might eventually point to a diachronic occupation of the site. Yet, the clear technological uniformity between the different scatters indicates that the site, if re-used, was occupied by groups belonging to the same "cultural" tradition.

The combined results from mineralogical, chemical and micromorphological analyses prove that at least two burning spots were present on the site. A first one only left scant evidence in the form of a red-coloring of the soil, resulting from in situ burning. As only few lithic artifacts have been found in the vicinity of this feature its anthropogenic origin can only be assumed from the chemical characteristics, in particular the presence of hematite and wüstite. The man-made character of the second firing place on the other hand is secured by the use of sandstones, imported to the site from the nearby hills and showing clear burning traces. No red-coloring of the soil was found associated with this hearth but this probably has to do with the deposition of ash underneath the sandstones, which faded away the red-coloring. Clearly this stone-structured

Table 5
Major and trace element concentrations of box P2. Red colors indicate the highest values, white average values and green cells have the lowest values. Bal = balance: 100%-amount of oxides.

Distance from bottom	SiO_2	CaO	P_2O_5	K_2O	Al_2O_3	TiO_2	Fe_2O_3
	%	%	%	%	%	%	%
37,5	63	0.26	0.21	1.1	1.4	0.38	1.5
29	53	0.29	0.13	1.1	1.5	0.40	1.7
24,5	34	0.43	0.14	1.2	2.7	0.41	3.9
17,5	35	0.39	0.36	1.1	2.1	0.43	2.6
13	38	0.39	0.21	1.2	2.2	0.43	3.1
13	42	0.43	0.16	1.2	2.7	0.47	3.5
12	45	0.42	0.30	1.2	2.3	0.47	2.6
10	36	0.38	0.14	1.2	1.9	0.42	3.3
3	44	0.36	0.14	1.2	1.8	0.43	2.0
	MnO	Bal	Zr	Sr	Rb	Ba	
	%	%	mg/kg	mg/kg	mg/kg	mg/kg	
37,5	0.02	32	479	45	40	304	
29	0.01	42	436	42	39	282	
24,5	0.02	57	440	43	48	302	
17,5	0.01	58	553	44	47	316	
13	0.02	54	628	56	50	318	
13	0.01	50	514	51	48	353	
12	0.01	48	570	51	47	339	
10	0.02	56	512	57	51	361	
3	0.01	50	518	52	48	323	

Table 6
Major and trace element concentrations of box P3. Red colors indicate the highest values, white average values and green cells have the lowest values. Bal = balance: 100%-amount of oxides.

Distance from bottom	SiO_2	CaO	P_2O_5	K_2O	Al_2O_3	TiO_2	Fe_2O_3
	%	%	%	%	%	%	%
31	42	0.27	0.12	0.96	0.55	0.34	1.6
23,5	51	0.33	0.38	1.2	2.3	0.44	2.1
16	37	0.34	0.13	1.1	1.8	0.37	3.4
13	36	0.31	0.13	1.1	1.6	0.38	2.7
8	37	0.38	0.14	1.2	1.8	0.41	2.5
2	32	0.40	0.22	1.1	1.7	0.34	3.0
	MnO	Bal	Zr	Sr	Rb	Ba	
	%	%	mg/kg	mg/kg	mg/kg	mg/kg	
31	0.02	55	432	42	40	249	
23,5	0.02	43	572	46	45	322	
16	0.01	56	465	48	43	384	
13	0.01	58	506	51	44	351	
8	0.01	56	456	50	46	320	
2	0.02	61	357	41	40	292	

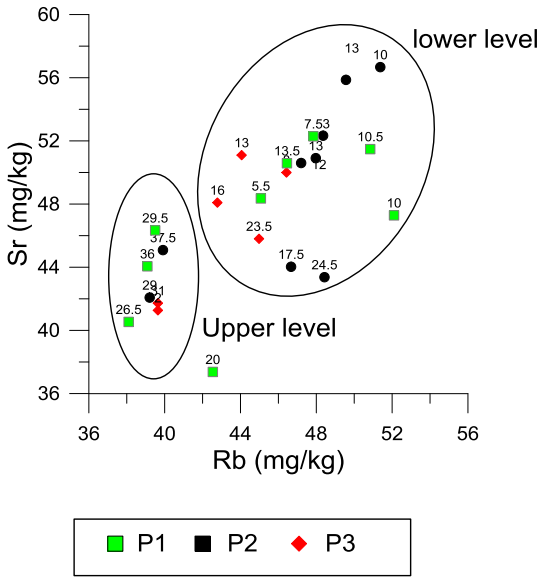


Fig. 15. Plot of rubidium (Rb) versus strontium (Sr). The number above the points indicates the distance above the bottom of the box.

hearth was the focus of different knapping activities, the most important one being situated immediately south of the hearth in an area with scattered sandstones. Here the distribution pattern of the lithics, nearly all coming from a single core, probably reflects a short knapping event conducted by a single knapper with the aim of producing highly standardized regular bladelets intended for making or retooling the hunting equipment. A second knapping post situated further away from the hearth was mainly focused on the knapping of local/regional flint.

The technological characteristics of the flint assemblages found in the different clusters are indicative of a highly skilled and elaborated knapping of the various flint types. Nodules and/or large frost fragments were carefully prepared (preparation of crested blades, intense platform preparation) and frequently rejuvenated in

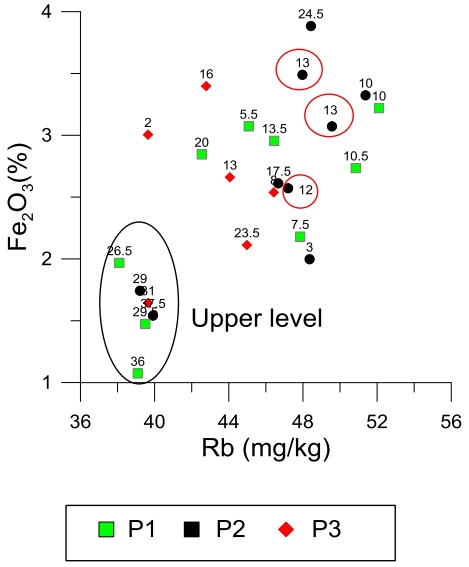


Fig. 16. Iron versus Rb variation in the three boxes. The red circles indicate the samples of the red-colored feature. The number above the points indicate the distance above the bottom of the box. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

order to obtain and maintain cores with a rather sharp angle and relatively flat to weakly convex exploitation tables. From these cores regular and narrow bladelets and occasionally short blades were struck most likely using a soft stone hammer (e.g. sandstone). The latter is deduced from the predominance of linear and pointed butts, the frequent occurrence of percussion undulations, the presence of butt splinters and the overall straight profile of the bladelets (Pelegrin, 2000). These straight bladelets were preferably used to produce microlithic armatures with backed edge and eventually a truncated end.

The use of a soft stone hammer in order to produce straight regular blade(let)s from cores with two opposite platforms seems to be typical for YD lithic traditions of both Northern and Southern Europe, such as the (Epi)Ahrensburgian (Deeben et al., 2000; Johanson and Stapert, 2000; Hartz, 1987), Belloisian or Long Blade (Barton, 1998; Fagnart, 1997; Valentin, 2008) and (Epi) Laborian Cultures (Langlais et al., 2014; Naudinot, 2008, 2013; Valentin, 2008) (Fig. 1). It contrasts sharply with the rather simple hard hammer knapping technique producing hardly standardized short blade(let)s and at some sites rather long bladelike flakes (*éclats alongés/laminaires*) from unprepared cores as found within the preceding cultures, such as the final Federmesser/Azilian (Bodu and Valentin, 1997; Célérier, 1993; Fagnart and Coudret, 2000) and Bromme (Fischer, 1997; Sørensen, 2010). However, the exact chronology of this fundamental technological shift is still vague as a result of a lack of secure radiocarbon dates and calibration problems due to the presence of several plateaus. In this context the radiocarbon date from Ruien is very important as it provides a very early date, situated right at the transition from the Allerød to the YD (ca. 11,000–10,750 cal BC), for the use of a soft stone hammer and the production of regular straight bladelets. This is even slightly older than the few dates obtained for the so far earliest Ahrensburgian – Alt Duvenstedt LA 121 (Clausen, 1998) and Remouchamps (Dewez, 1974) – and Laborian sites – Pont d'Ambon (Célérier, 1993; Célérier et al., 1997) and Rueil Malmaison (Bodu, 2000), which situate roughly between ca. 10,800 and 10,600 cal BC, corresponding to the initial stage of the YD (Table 7; Fig. 18). At the latter two sites the evidence for a sophisticated regular blade debitage by means of a soft stone hammer is very convincing. Although no detailed technological analysis has so far been conducted or published at the two mentioned Ahrensburgian sites, the presence of cores with sharp angles and relatively flat exploitation tables, called "*nucléus en éventail*" (Naudinot, 2013) clearly refers to the use of a soft stone hammer technique. Hence these 4 sites together with Ruien testify that soft stone hammers and related regular blade(let) production were already in use from the very start of the YD, and judging by the Ruien date perhaps even at the very end of the Allerød in a vast area, from the French Dordogne over the Paris basin and Belgium till the Baltic area. Interestingly the youngest dates for the Late *Federmesser* and Bromme Cultures within this extensive area situate around the same period (Fig. 18), suggesting that the technological change from unstandardized to high quality regular blade(let) production inducing a shift from hard to soft stone hammer utilization, occurred in the course of the initial stages of the YD. Unfortunately the resolution of the scant radiocarbon evidence does not enable to assess whether there was a temporary overlap between both technological traditions or whether they were strictly diachronic. Furthermore it is questionable whether new and more accurate radiocarbon dates with standard deviates smaller than 50 years will allow to tackle this chronological discussion given the presence of a radiocarbon plateau around 11,100–11,000 uncal BP.

The increased importance of a refined and standardized bladelet production, as observed at Ruien, might be a direct response to changing climate of the YD. Several ethnographic studies have

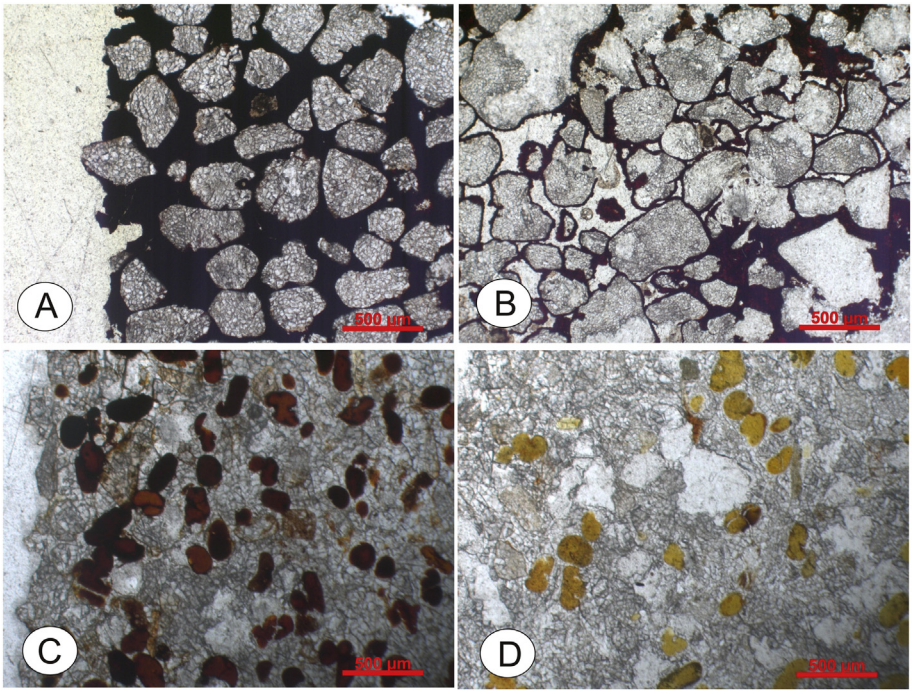


Fig. 17. Micrographs of ferruginous sandstone with quartz grains in iron rich cement: (A) crust sample (B) core sample. Glauconiferous sandstone: (C) crust sample with brownish discoloration of yellow-green glauconite grains and (D) core sample. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

suggested that as subsistence resources become poorer, technological complexity tends to increase in view of minimizing risk and failure to acquire resources (for references see Mackay and Marwick, 2011). According to Collard et al. (2005) temperature is an important proxy for risk in modeling technological variability among hunter-gatherer groups. Cooler temperatures are generally associated with increased risk because of a reduction in the availability of resources. According to some models (Mackay and

Table 7
List of radiocarbon dates from sites dated to the transition between the Allerød and YD. Badly or unassociated charcoal dates have been excluded from the list. Italics dates are considered most reliable based on the protocol from Crombé et al. (2013a).

Site	Country	BP date	Lab code	Dating material	Sample context	Reference
Ruien	BEL	*10,962 ± 48*	RICH-20143	Ash-layer	Hearth	This paper
Late *Federmesser* Culture						
Doetichem	NED	10,930 ± 50	GrA-13388	Calcined bones	Hearth dump	Johanson et al., 2000
"Dichteren"		10,880 ± 50	GrA-13387	Calcined bones	Hearth	
		10,870 ± 50	GrA-13686	Charcoal	Hearth	
Hangest-sur-Somme III-1 Niv. Sup.	FRA	*10,920 ± 90*	OxA-4935	Bone (auroch)	Cultural layer	Fagnart, 1997
Milheeze I	NED	11,150 ± 60	GrA-23908	Calcined bones	?	Lauwerier and Deeben, 2011
Rueil-Malmaison "Le Closeau" Niv. Sup.	FRA	*10,840 ± 110*	OxA-6637	Bone	Hearth	Bodu and Valentin, 1997
		10,650 ± 75	Lyon 206	Charcoal	Hearth	
		10,670 ± 110	Lyon 7189	Charcoal	Cultural layer	
Saleux 114	FRA	*11,010 ± 80*	OxA-4932	Bone (auroch)	Cultural layer	Fagnart, 1997
Unité 15		*10,800 ± 140*	OxA-4933	Bone (auroch)	Culturalayer	Fagnart, 1997
Wierden	NED	10,720 ± 60	GrA-23973	Calcined bones	Bone cluster	Lauwerier and Deeben, 2011
"Enterse Akkers HS-1"		10,690 ± 50	GrA-24847	Calcined bones	Bone cluster	
Westerbeers	NED	11,030 ± 45	GrA-32787	Calcined bones	?	Lauwerier and Deeben, 2011
"NO 226-115"						
Bromme Culture						
Bromme		*10,720 ± 90*	AAR-4539	Bone Alces alces	Cultural layer	Heinemeier and Rud, 2001
Fensmark		10,810 ± 120	OxA-3614	Charcoal	Solifluction layer	Fischer, 1996
Trollesgave		*10,826 ± 49*	AAR-16019	Charcoal Salix	Cultural layer	Fischer et al., 2013
		11,070 ± 120	K-2641	Charcoal Salix, Betula, Populus	Cultural layer	Fischer, 1996
Early Ahrensburgian Culture						
Alt Duvenstedt	GER	*10,810 ± 80*	AAR-2245	Charcoal	Hearth	Kaiser and Clausen, 2005
LA 121	GER	*10,770 ± 60*	AAR-2245.2	Charcoal	Hearth	
Remouchamps	BEL	*10,800 ± 110*	OxA-4191	Rangifer bone with cutmarks	Cultural layer	Charles, 1994
Laborian Culture						
Bad Breisig	GER	*10,840 ± 60*	GrA-17493	Charcoal Pinus	Hearth	Baales et al., 2001
Pont d'Ambon couche 2	FRA	*10,730 ± 100*	GifA-99102	Bone Canis	?	Célérier et al., 1999
Rueil-Malmaison "Le Closeau" Locus 25	FRA	10,885 ± 85	Lyon 564	Charcoal	Hearth ?	Teyssandier, 2000
		10,755 ± 90	Lyon 563	Charcoal	Hearth ?	

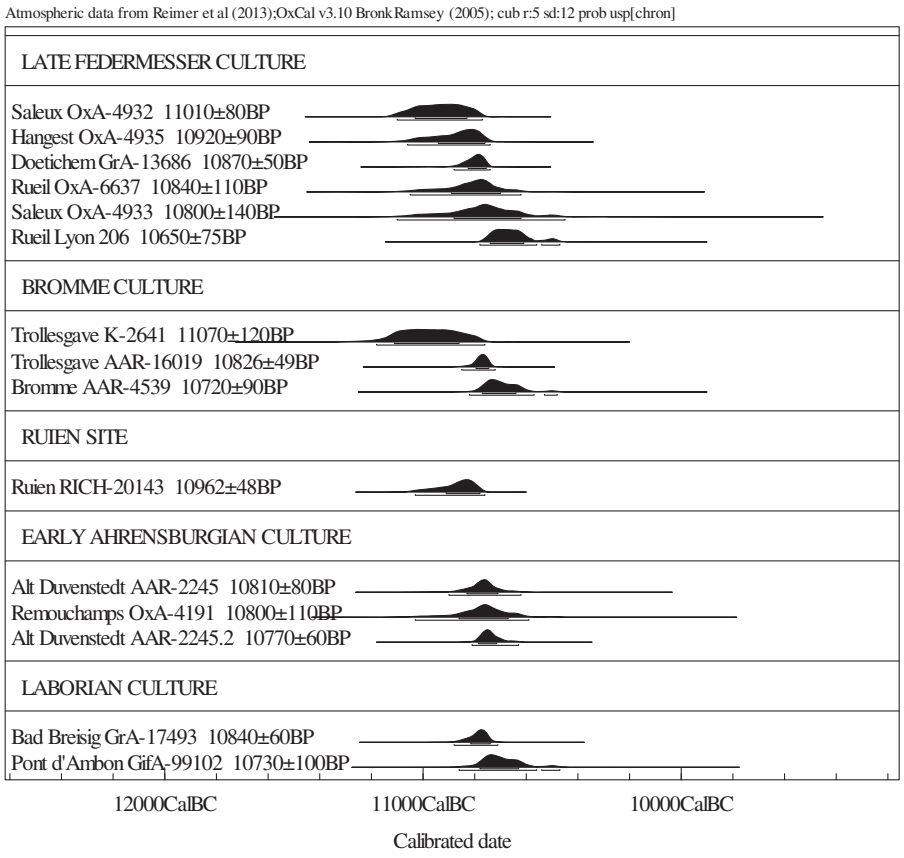


Fig. 18. Calibrated dates from sites belonging to different techno-complexes at the transition between the Allerød and Younger Dryas.

Marwick, 2011) increased risk ultimately results in amplified investment in lithic technology and possibly raw material procurement too. Applied to the YD the cooler conditions and harsher environment might have urged hunter-gatherers to invest more in the production of their projectile equipment, by using standardized blade(let)s which were much more uniform and balanced in shape and dimensions compared to those from the preceding *Federmesser* Culture. The increased importance of microblades is generally considered to be an essential adaptive advantage to people coping with life in cooler and open environments, allowing them to be more mobile (Elston and Brantingham, 2002; Elston et al., 2011; Goebel, 2002; Yi et al., 2013).

Clearly the start of the YD did not only affect the knapping techniques, but apparently also led to major changes in the raw material procurement strategies. Compared to the *Federmesser* assemblages from the Scheldt valley (Crombé et al., 2011), there is a much greater diversity of exogenous flint used at Ruien. Besides a black to darkbrown fine-grained flint, representing on average 7% of the raw material and originating from outcrops at distances of maximum 80 km–130 km, *Federmesser* hunter-gatherers exclusively knapped local flint of very mediocre quality (small intensively frost fractured nodules). At Ruien exotic flint has been imported from much further away, as far as 250 km east, and from many more sources (valleys of the Meuse, Moselle and Rhine). Similar observations have been reported in adjacent study-areas. Floss (1994) mentions transport with a mean distance of 227 km and a maximum of 650 km for tanged-point complexes in the Middle Rhine region. This marked change in the circulation of raw materials most likely indicates increased mobility and lithic raw material procurement territories from the onset of the cold YD. Important changes are also visible in the lithic armatures. Despite the extreme fragmentation of the Ruien armatures, it is clear that a profound microlithisation took place with respect to the *Federmesser*. Clearly armatures are made on very small bladelets, having dimensions which are very comparable to Mesolithic microliths (Crombé, 1998).

6. Conclusions

The small site of Ruien has yielded data which is interesting in different aspects. From a technological point of view it provides a reliable radiocarbon date for the use of the soft stone hammer technique to produce regular straight blade(let)s from the very start of the YD, or maybe slightly earlier. Within the context of the differential site density during the YD between western and northern Europe, as discussed in the introduction, the site of Ruien clearly indicates that the scarcity of YD sites in the West may well be biased by a lesser visibility compared to the Ahrensburgian of the North. Indeed, due to the small dimensions of the armatures and their extreme fragmentation as well as the bladelet oriented debitage, YD sites may be very difficult to distinguish from Mesolithic assemblages, in particular those dated to the earliest Boreal stage (Crombé et al., 2014). Only a detailed technological investigation might allow the differentiation, although the systematic use of a soft stone hammer on cores with relatively sharp angles (65°–75°) has also been attested on Early Mesolithic assemblages from the Scheldt basin (Perdaen et al., 2008). The technological differences are rather subtle on the level of frequencies of certain butt types, core rejuvenation, and bladelet morphology. In most cases, however, only radiocarbon or stratigraphic evidence can

help, but as the majority of sites are plowed surface sites this kind of evidence is generally lacking.

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